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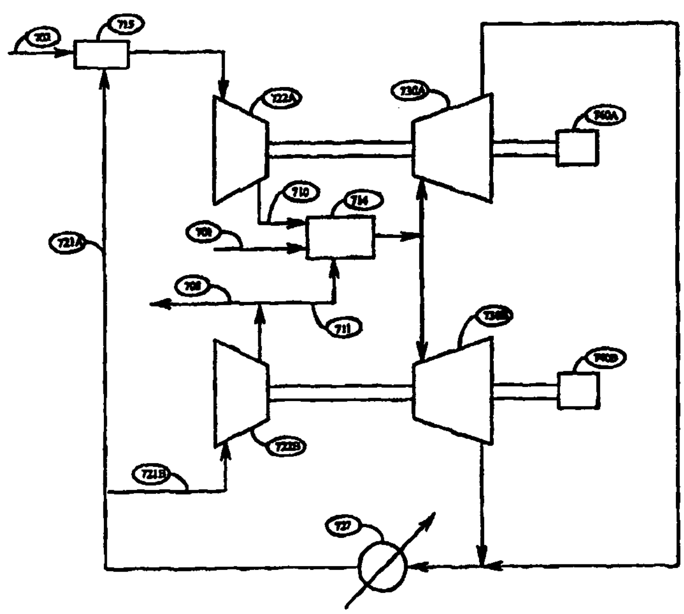

(57) Abstract

Method for low pollution power generation by combusting a fuel with a supply of highly concentrated oxygen in a combustion chamber (714), to which recirculated combustion products are introduced for temperature control, characterized in that all or parts of the combustion products are cooled (727) to an appropriate temperature which keeps all or most of the water vapor from condensing from said products, before said products are compressed and recirculated to the combustion chamber.

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Improved Power Plant with Carbon Dioxide Capture

Field of the invention

The present invention relates to a combustion process, of the kind indicated in the introduction of claim 1, yielding exhaust comprising mainly of water vapour and carbon dioxide and facilitating removal of carbon dioxide from the exhaust.

Background of the invention

The increasing energy demand world wide combined with an increasing environmental awareness has initiated extensive research programs for developing alternative energy sources and/or alternative usage of known energy sources. Several alternative energy sources are available today in small scale, but only nuclear and fossil fuel based power plants can supply large outputs in a cost-effective manner. The nuclear power plant suffers from safety risks and problematic radioactive waste disposal. Future development of nuclear power plants seems very limited, mostly because of political unwillingness. As a result, the remaining alternative to fill the present energy gap are thermal power plants based on fossil fuels.

The International Conference in Kyoto in Japan, 1997, focused on the global green house effect. Carbon dioxide (CO_2) emission from thermal power plants was one of the concerns. As a result of this meeting, several countries agreed to limit their CO_2 emissions and establish a maximum emission

level per year. Some countries have also put separate taxes on CO_2 emissions. These new regulations are intended to promote research for CO_2 removal from exhaust gases.

Multiple proposals have been published for power cycles utilizing highly concentrated oxygen supplied from air separation units to combust fossil fuels in combustion chambers where the outlet temperature is controlled by recirculation of combustion products. The energy in the combustion products is converted to electric power via gas turbines and optionally extracted in a waste heat recovery unit. The steam may be used to generate electric power in a steam turbine or for district heating. Before compression to combustion pressure the combustion products are cooled down, condensed water is discarded and parts of the remaining combustion products are removed from the cycle. The reason for cooling the combustion products is to reduce compressor work and comply with standard compressor inlet temperatures. The CO_2 produced during combustion in these processes may easily be separated by cooling the products to CO_2 liquefaction temperature. Earlier work has therefore proposed low pressure takeoffs of combustion products upstream the compressor.

This cycle has an acceptable thermal efficiency with a combined cycle setup and will produce CO_2 that may be disposed of in an environmentally friendly manner. Other pollutants normally present

in the combustion products, such as oxides of nitrogen, may be similarly disposed of. A main technical obstacle for this cycle/process is that turbines optimized for this service presently do not exist. The most important fluid property deviation in this respect is the increase of molecular weight relative to that of air. Other deviations are lower sonic velocity and different kappa-value.

US patent 5724805 by Golomb shows a method for low pollution power generation by combusting a fossil fuel with high concentration oxygen in a combustion chamber, to which a coolant is introduced, and the latent heat of the combustion products are used for heating purposes or converted to mechanical and/or electrical energy. A part of the combustion products after cooling to an appropriate temperature is optionally used as a diluent for the fossil fuel and the oxygen, and is injected as a coolant to the combustion chamber. The invention is primarily aimed at heat integration between the air separation unit and the CO_2 condensing unit, in a closed cycle with internal combustion.

US patents 5802840, 5724805, 4498289, 4434613 and 3736745 condenses and discards the water from the combustion products, and use mainly carbon dioxide as working medium. This gives the cycle fluid a high molecular weight.

US patent 5715673 use water as working medium. The "state of the art" on turbines for water is conven-

tional steam turbines. If the produced liquid water is recycled into the process, there may be a corrosion problem caused by the acidic water.

US patent 5247791 and 3628332 recycle both the water and the gases in the combustion products. The water is separated from the combustion products by condensation. The water, which is acidic, may cause corrosion problems.

The patents above neither extract the excess combustion products at high pressure nor do they claim mixing of oxygen with the working medium before combustion. This combination, as suggested by the present invention, will make two parallel compressors beneficial, e.g. as shown on fig. 7 and 8.

Object of the invention

The present invention seeks to minimize the above mentioned obstacles by keeping the service conditions for the turbine as close to conventional as possible. The present invention also allows simpler and safer plants to be built.

Brief description of the invention

The present invention is based on two well known main concepts. They are, the concept of combustion of fossil fuels with a supply of highly concentrated oxygen, and the use of the combustion products, or parts of them, as the main part of the working fluid in a closed cycle.

The main technological challenge for current methods utilizing this concept is the development of a gas turbine with the required performance for the cycle fluid composition in question. The most important fluid property deviation in this respect is the increase of molecular weight relative to that of air. This deviation may be avoided by recirculating combustion products containing water vapor to the combustion chamber. The present invention proposes to do this by raising the suction temperature of the compressor(s) such that no or only small amounts of water vapor will condense in the main cycle loop. This represents a major change from current designs and engineering practice, where the compressor suction temperature is kept as low as possible in order to minimize compressor work. With an increased suction temperature the required compressor work will increase significantly, but that will be offset by higher temperature in the recirculated gas entering the combustion chamber, more heat output at high temperature from the waste heat recovery unit and a reduction in the amount of low-temperature heat with low usefulness being removed from the cycle. The impact on the overall efficiency by the proposed method is small. As well as gaining control over the molecular weight of the cycle fluid it will reduce the deviations of the cycle fluid from conventional sonic velocities and kappa-values. The proposed method can also avoid corrosion problems caused by acidic condensed water. Alternatively, the condensed water could have been pumped to combustion pressure,

evaporated and introduced to the combustion chamber (ref. US 5247791), but that results in a lower efficiency than the proposed method.

Disposal of the CO_2 produced from a large scale power plant will most likely be achieved by injection into an underground reservoir. This will require an injection pressure higher than the combustion pressure. A compressor and combustion chamber that allows the excess parts of the recirculated combustion products to be extracted downstream the compressor and upstream the combustion chamber is proposed. Combustion products removed at said location will not require separate compressors for compression from compressor suction pressure to combustion pressure. This will allow the plant to be built with fewer components and reduced cost.

Delivery of oxygen at combustion pressure is required and compression of highly concentrated oxygen represents a safety risk. In addition, compression of the required volume of combustion products in a large scale power plant may be difficult to achieve in a single conventionally sized compressor. Thus, in order to minimize safety risks and to obtain a practical compression setup, the present invention proposes to mix oxygen with part of the recirculated combustion products and compress this in parallel with the rest of the recirculated combustion products. The compression of combustion products and of oxygen diluted with combustion products may be performed in any number of parallel

compressors. With this method, the flexibility when mixing the streams into the combustion chamber will be good. Adjustment of flow division between the compressors in order to obtain a practical design, e.g. with respect to compressor drivers, will be possible.

The present invention relates to a combustion process which facilitates removal of CO_2 from its exhaust. Highly concentrated oxygen, from for instance an air separation unit (ASU) or other apparatus for the production of oxygen from air, is mixed with a fossil fuel, e.g. natural gas in a combustion chamber. The resulting combustion products comprise mainly water vapour and CO_2. Part of the exhaust is cooled and recycled back to the feed gases and/or combustion chamber to control the combustion zone and combustion exit temperature. The exhaust consists mainly of CO_2, H_2O, N_2, Argon and O_2. The CO_2 can be disposed of as gas, liquid or hydrates into subterranean formations, into producing formations, onto the seabed, or used commercially.

The present invention improves the combustion process by keeping vapor from condensing to water in the system, optionally using parts of the combustion products as a diluent for the oxygen before compressing and using the oxidant in the combustion chamber, and optionally withdrawing parts of the combustion products from the cycle after having been compressed to combustion pressure, but before being fed to the combustion chamber.

The advantages of this improved combustion process can be summarised as follows:

-the form of the exhaust, i.e. largely water vapour and CO_2, makes the CO_2 retrieval easier,

-the volume of the related equipment is considerably reduced,

-the number of related equipment is reduced,

-the temperature of combustion is controlled,

-the safety is improved,

-corrosion problems are reduced,

-existing equipment is easier to adapt to teh process.

Brief description of the drawings

Fig. 1 is a schematic diagram showing the principles of burning fossil fuels with highly concentrated oxygen and recycling of combustion products.

Fig. 2 is a schematic diagram showing a closed steam cycle heat engine.

Fig. 3 is a schematic diagram showing an open cycle gas turbine type heat engine.

Fig. 4 is a schematic diagram showing a closed cycle gas turbine type heat engine with the combustion external to the heat engine cycle.

Fig. 5 is a schematic diagram showing a closed cycle gas turbine type heat engine with the combustion internally in the heat engine cycle.

Fig. 6 is a schematic diagram showing one alternative for the disposal of combustion products generated,

Fig. 7 is a schematic diagram showing a first embodiment of the present invention,

Fig. 8 is a schematic diagram showing a second embodiment of the present invention,

Fig. 9 is a schematic diagram showing a third embodiment of the present invention, and

Fig. 10 is a schematic diagram showing a fourth embodiment of the present invention.

Detailed description

Fig. 1 shows the principle of burning fossil fuels with pure oxygen and recycling of exhaust with heat transfer to the working fluid of the heat engine. A fuel is supplied through inlet line 101, its flow rate controlled by the control valve 103 and going to the burner arrangement 113 in the combustion chamber 114. Highly concentrated oxygen, for instance from an air separation unit, is supplied through inlet line 102, its flow rate being controlled by a control valve 104. The oxygen then enters a mixer 109 wherein it is mixed with a suitably large portion of the combustion product which has been cooled by giving off heat to the working fluid of the heat engine cycle in heat transfer

unit 115. The admixture of cooled combustion products to the oxygen, controlled by a control valve 106 and conducted through the line 110 to the mixer 109, gives control of flame temperature levels. Thus, when the diluted oxygen and the fuel burns in the burner arrangement 113 the temperature is controlled at levels acceptable to the combustion chamber design and materials. A further admixture of recirculating cooled combustion products takes place through a control valve 107 which is connected to the combustion chamber 114 outer wall by the line 111; this admixture flow is distributed into the space between the combustion chamber outer wall and the combustion chamber inner liner 112 which is suitably perforated for admission of more cooled combustion products, the purpose being reduction of hot combustion products temperatures to levels acceptable to downstream equipment such as the heat transfer surfaces 121 of the heat transfer unit 115.

The combustion products are, after their cool-down in the heat transfer unit 115, taken through a duct 118 to a motor driven recirculation fan 119 and is discharged through a duct 120 back to the control valves 106 and 107 and also to a control valve 105 controlling flow through the duct 108.

Heat from the combustion products passing through the heat transfer unit 115 is transferred to the heat engine working medium which enters the unit

115 through a connection 116 and discharged through a connection 117.

An integrated control system for the control of the control valves 103, 104, 105, 106, 107, of the re-circulation fan 119 is required but not shown in fig. 1. Likewise not shown are the sensors giving inputs to the integrated control system.

The flow through the duct 108 goes to a combustion products disposal system (not shown) wherein the products, mainly water vapor and CO_2 gas, can be separated and liquefied through compression and cooling. The CO_2 can then be disposed of in a manner preventing its entering the atmosphere.

Fig. 2 shows one alternative system in which the principle of burning fossil fuels with pure oxygen and recycling of exhaust can be used, namely in a steam cycle. The fuel enters through inlet line 201 and the high concentration oxygen enters through inlet line 202. Recirculating cooled combustion products supplied through line 210 are mixed with the supplied oxygen before going to a combustion chamber 214 where combustion of the fuel takes place with flame zone temperatures controlled by the admixture of the cooled combustion products.

Further admixture of cooled combustion products supplied through the line 211 gives further control of the hot combustion products temperature before they enter the steam generator 215 which supplies

steam through the line 217 to a steam turbine part 230 of the plant.

The steam turbine 230 drives the load 240. Condensed steam returns to the steam generator 215 through the line 216.

The combustion products, cooled by giving off heat in the steam generator, are recirculated by the recirulation fan 219, most of the flow going through lines 210 and 211 back to the combustion chamber 214. A mass flow rate equal to the combined supply of combustion reactants supplied through the lines 201 and 202 is let out of the recirculation loop through the line 208 and goes to disposal. The combustion products contain mainly CO_2 and water vapor which through compression and cooling can be separated and disposed of as liquids.

Control valves controlling the flows of fuel, oxygen and recirculating cooled combustion products are not shown in fig. 2. For these valves reference is made to fig. 1 and its descriptive text.

Fig. 3 shows another alternative usage of the principle of burning fossil fuels with pure oxygen and recycling of exhaust, in this case as an external combustion chamber with transfer of heat into the working medium of an open cycle gas turbine. Air enters the gas turbine 330 through the inlet line 321 and is compressed in the compressor sections 322A and B with an intercooler 323 in between the

two compressors. The compressed air flows to the heat exchanger 315 and receives heat from the hot combustion products emanating from the combustion chamber 314. The heated air is next expanded in the turbine section 330 of the gas turbine. Power generated in the turbine drives the compressor sections 322A and B and a load 340. Some of the energy remaining in the exhaust from the turbine can be recovered in a waste heat recovery unit 331 before the air is disposed to the atmosphere through the exhaust duct 332.

The fuel is supplied to a combustion chamber system though the inlet line 301; the high concentration oxygen enters through the line 302. Recirculating cooled combustion products supplied through the line 310 mixes with the supplied oxygen before going to the combustion chamber 314 where combustion of the fuel takes place with flame zone temperatures controlled by the admixture of the cooled combustion products.

Further admixture of cooled combustion products supplied through the line 311 gives further control of the hot combustion products temperature before they enter the heat exchanger 315 where heat is given off to the working medium of the gas turbine. The cooled combustion products are recirculated by the recirulation fan 319, most of the flow going through the lines 310 and 311 back to the combustion chamber 314.

A mass flow rates equal to the combined supply of the combustion reactants supplied through the inlet lines 301 and 302 is let out of the recirculation loop through the line 308 and goes to disposal.

The combustion products contain mainly CO_2 and water vapor which through compression and cooling are separated and disposed of as liquids.

Control valves controlling the flows of fuel, oxygen and recirculating cooled combustion products are not shown in fig. 3. For these valves reference is made to fig. 1 and its descriptive text.

Fig. 4 shows yet another alternative system in which the principle of burning fossil fuels with pure oxygen and recycling of exhaust can be used, namely in an closed cycle gas turbine with an external combustion chamber. The recirculating working medium of the gas turbine enters the cycle through line 421 and is compressed in the compressor sections 422A and B. In between the two compressors the working medium is led through the intercooler 423 in order to reduce the compressor work and the compressor discharge temperature. The working medium passes from the compressor to a recuperator/regenerator 424 receiving some heat from the working medium exhausting from the expander turbine 430.

The working medium being heated next goes to the heat exchanger 415 where heat emanating from a com-

bustion chamber 414 is added. The working medium is then expanded in the turbine 430 which drives the compressor section 422A,B and also the load 440. The turbine exhaust then passes to the recuperator/regenerator 424 where heat is given off to the working medium coming from the compressor section 422A,B. The working medium which has been through the expander turbine and the recuperator/regenerator next goes to the precooler 427 where its temperature is taken down as low as practically possible before the working medium is led back into the line 421 and re-enters the compressor section.

The fuel is supplied to the combustion chamber system through the inlet line 401; the high concentration oxygen enters through the inlet line 402. Recirculating cooled combustion products supplied through the line 410 mixes with the supplied oxygen before going to the combustion chamber 414 where combustion of the fuel takes place with flame zone temperatures controlled by the admixture of the cooled combustion products.

Further admixture of cooled combustion products supplied through the line 411 gives further control of the hot combustion products temperature before they enter the heat exchanger 415 where heat is given off to the working medium of the gas turbine.

The cooled combustion products are recirculated by a recirulation fan 419, most of the flow going

through the lines 410 and 411 back to the combustion chamber 414.

A mass flow rates equal to the combined supply of combustion reactants supplied through the inlet lines 401 and 402 is let out of the combustion products recirculation loop through the line 408 and goes to a disposal system, as the one suggested in Fig. 6.

The combustion products contain mainly CO_2 and water vapor which through compression and cooling can be separated and disposed of as liquids.

Valves controlling the flows of fuel, oxygen and recirculating cooled combustion products are not shown in fig. 4. For these valves reference is made to fig. 1 and its descriptive text.

Fig. 5 shows still another alternative system in which the principle of burning fossil fuels with pure oxygen and recycling of exhaust can be used, in this case consisting of a closed cycle gas turbine, but with internal combustion. The recirculating working medium of the gas turbine enters the compressor sections through a line 521, wherein it is compressed in a compressor sections 522A and B with intercooling in 523 to reduce compressor work and the compressor discharge temperature.

The working medium then passes from the compressor section 522B to the recuperator/regenerator 524 re-

ceiving some heat from the working medium exhausting from the expander turbine 530.

The working medium being heated next goes to the combustion chamber 514 but is divided into two streams before entering. The stream through line 510 is mixed with the supply of high concentration oxygen, which is supplied at 502. The admixture of working medium to the oxygen is used to control combustion flame temperature at levels acceptable to combustion chamber design and materials.

The second supply of working medium to the combustion chamber enters through line 511 and is used to control the combustion chamber exit temperature at levels acceptable to the expander turbine 530 which is next in the working medium loop.
Fuel is supplied to the combustion chamber through connection 501.

Working medium exhausting from the expander turbine 530 next flows to the recuperator/regenerator's 524 hot side and gives off heat to the working medium coming from in the compressor section 522B.

The working medium coming from the expander turbine 530 through the hot side of the recuperator/regenerator 524 next flows through precooler 527 where it is cooled down as low as is practical before flowing to scrubber 529 where condensed water vapor is separated out and disposed of through line 529.

More working medium is disposed of through line 508 and goes to compression and cooling for separation and liquefaction of the main components CO_2 and water. Total disposal mass flow rates equals total rate of supplying fuel and high concentration oxygen into connections 501 and 502, respectively.

Valves controlling the flows of fuel, oxygen and the distribution of working medium flow through the combustion chamber 514 are not shown in fig. 5. For these valves reference is made to similar valves in fig. 1 and its descriptive text.

Fig. 6 shows a method for separation of in which CO_2 and water vapor are disposed. Surplus combustion products released from the combustion products recirculation loop through lines 108, 208, 308, 408, 508 shown on Figs. 1, 2, 3, 4, 5, respectively, are led into the disposal system through line 608.

The disposal system main components are compressors 652, 653, 654, coolers/condensers 655, 656, 657, 661 and scrubbers 665, 666, 667. The main ingredients of the combustion products are CO_2 and water vapor; with minor components, such as nitrogen, oxygen, and argon, present.

The surplus combustion products supplied to the disposal system through line 608 is compressed in the compressor stage 652, cooled with condensation

of water vapor in cooler 655. The condensed water is separated out from the rest of the combustion products in the scrubber 658 and disposed of through line 665.

The pressure is further increased and more water vapor condensed out as the combustion products passes through compressor 653, cooler/condenser 656 and scrubber 659 producing further water drainage through line 666.

The number of steps of compression depends mainly on the pressure in line 608. Fig. 6 is based on the assumption that 3 steps of compression is required to take the pressure up to approximately 72 bara out of the last compressor stage 654.

The compressor stages are driven by the driver unit 664, normally a motor with a speed-increasing gear.

More water vapor may be taken out by cooling the combustion products in cooler 657 and taking condensed water out in scrubber 660 through the drain 667.

The pressure of the remaining combustion products going into the next cooler 661 is assumed to be kept to 70 bara. The main ingredient is CO_2, additionally small amounts of nitrogen, oxygen and argon; the water vapor content is very small after the preceding condensation/removal of water. If advantagous with respect to corrosion in downstream

lines, a dehydration package for removal of water vapor may easily be installed at an appropriate point between compressor 652 and pump 663.

Taking the temperature of the remaining combustion product down in cooler 661 causes the CO_2 to condense to CO_2 liquid which is then removed in scrubber 662, drained out through a line to a pump 663 where the CO_2 liquid can be pumped up to a pressure suitable for injection of the liquid into a geological formation, thus avoiding the release of the CO_2 to the atmosphere.

The remaining gaseous ingredients, mostly nitrogen and argon which entered the system as contaminants in the oxygen or fuel are disposed via line 669 together with any excess oxygen remaining in the combustion products after combustion of the fuel.

An integrated system of sensors and controls are required for the disposal system alternative outlined here, but are not shown in fig. 6, can however be arranged using existing hardware and technology.

Prefered embodiment

The given examples illustrate possible usage of the present invention, but does not seek to include all possible setups for usage of the invention. It should be emphasized that not all aspects of the method need to be implemented for the method to be

advantageous. The given examples of usage are possible to apply in the following scenarios:

- Large land based gas fired power plants without discharge of CO_2 to the atmosphere (typically 400 MW).
- Offshore gas fired power plants, typically 50MW, without discharge of CO_2 to the atmosphere. The potential benefits of low priced associated gas and the saving of CO_2 penalty (if applicable), will significantly improve plant economy.

In fig. 7 the present invention is shown used in a parallel shaft configuration, where two compressors are driven by two turbines. Fuel line 701, fuel, e.g. natural gas, an oxidant stream 710 primarily composed of oxygen mixed with combustion products, and a coolant stream of recirculated combustion products 711 are supplied to the combustion chamber 714. The combustion chamber 714 may be constructed as two functionally similar combustion chambers, one installed on each of the two gas turbines, 730A and 730B. The flow rates of streams 701, 710 and 711 are selected to give appropriate temperatures both in the flame and in the products exiting the combustion chamber. After leaving combustion chamber 714, the products are split into two streams, one passing through turbine 730A and one passing through turbine 730B, the turbines driving generators 740A and 740B. After passing through the turbines, said product streams are mixed and passed through a waste heat recovery unit 727 where the

products are cooled. This may be done in a heat recovery steam generator for supply to a steam turbine and/or for use for district heating. If a heat recovery steam generator is used, further cooling to the appropriate compressor suction temperature may have to be applied. It is advantageous to utilize as much of the heat removed in the heat recovery unit 727 in a steam system (not shown on the figure) as possible. Furthermore it is advantageous to cool as much as possible without condensing water vapor. The stream of cooled combustion products coming out of the heat recovery unit 727 is split into two streams, 721A and 721B. Stream 721B is compressed in compressor 722B, a suitable flow of combustion products 708 is withdrawn from stream 711 downstream the compressor exit and the rest is injected into the combustion chamber 714 as coolant. The high pressure products 708 may be cooled, condensed water separated out and the rest, mostly CO_2, may be compressed and injected into an underground reservoir. Stream 721A is mixed with an appropriate amount of oxygen coming through line 702 in mixer 715. The oxygen may be produced in a cryogenic or membrane air separation unit. The mixed oxygen and combustion products coming out of the mixer is compressed in compressor 722A and introduced in the combustion chamber 714 as oxidant.

In fig. 8 the present invention is shown used in a parallel shaft configuration, one compressor driven by a gas turbine and one compressor driven by a steam turbine. The combustion products are fed to

turbine 830A and then passed to the waste heat recovery 830A driving generator 840 and then passed to the waste heat recovery unit 827. The steam turbine 830B is fed with steam (not shown on the figure) generated in the waste heat recovery unit, 827. Otherwise this configuration is similar to the one shown in fig. 7.

In fig. 9 the present invention is shown used in a single shaft configuration driven by a turbine. Compressor 922A and 922B are both driven by turbine 930 which also drives generator 940. Otherwise this configuration is similar to the one shown in fig. 8.

In fig. 10 the present invention is shown in a one-axle configuration driven by a turbine. The combustion products exiting waste heat recovery unit 1027 are fed to a compressor 1022 driven by turbine 1030 through line 1021. A suitable flow of combustion products 1008 is withdrawn from stream 1011 downstream the compressor exit. These high pressure products 1008 may be cooled, condensed water separated out, and the rest, mostly CO_2, may be compressed and injected into an underground reservoir. Stream 1011 is split into two, one is mixed with stream 1002, which contains highly concentrated oxygen and the other is injected into the combustion chamber as a coolant stream. The split ratio of stream 1011, the flow rates of streams 1001 and 1011 are selected to give appropriate temperatures in the flame and in the products exiting the com-

bustion chamber. Otherwise this configuration is similar to the one shown in fig. 9.

Claims

1. Method for low pollution power generation by combusting a fuel with a supply of highly concentrated oxygen in a combustion chamber (714), to which recirculated combustion products are introduced for temperature control,
characterized in that all or parts of the combustion products are cooled (727) to an appropriate temperature which keeps all or most of the water vapor from condensing from said products, before said products are compressed and recirculated to the combustion chamber.

2. Method according to claim 1,
characterized in that parts of the combustion products after cooling are used as a diluent for the oxygen (715) and that this mixture of combustion products and oxygen thereafter is compressed separately from the remainder of said products and is used as oxidant in the combustion chamber (710).

3. Method according to claim 1 or 2,
characterized in that parts of the combustion products are withdrawn from the cycle (708) after having been compressed to combustion pressure but before being fed to the combustion chamber.

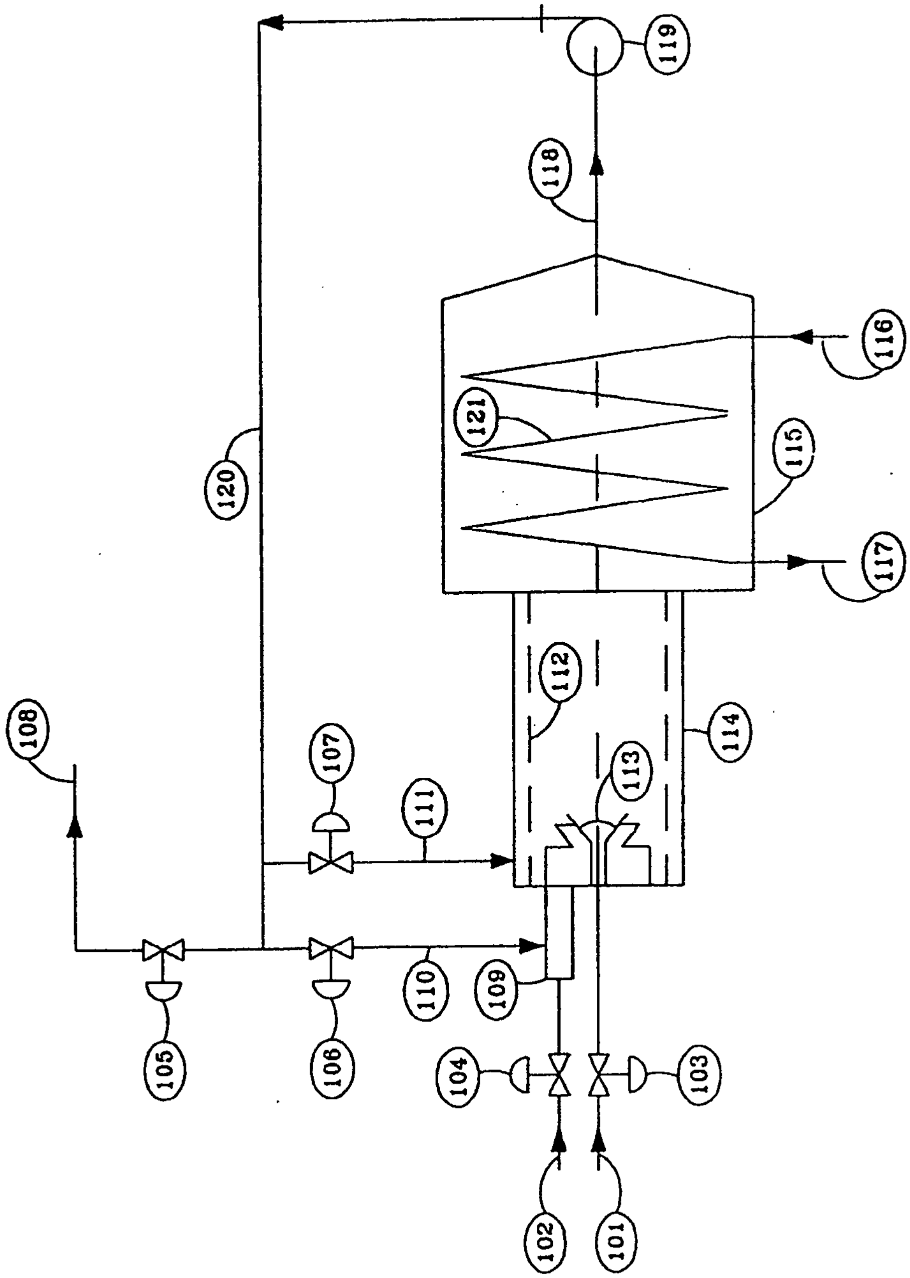
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FIG. 1

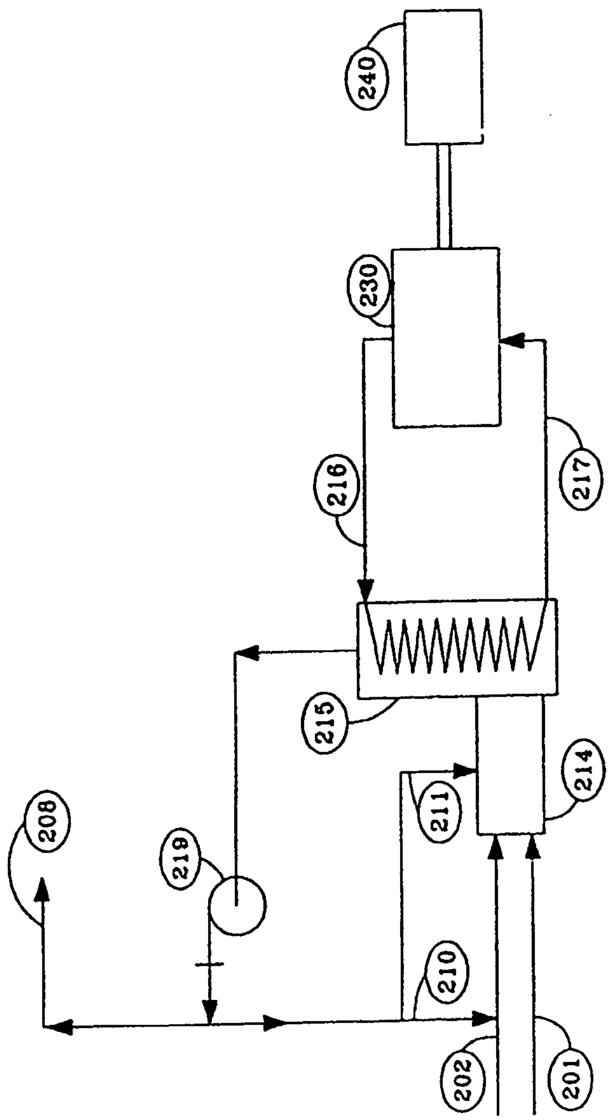
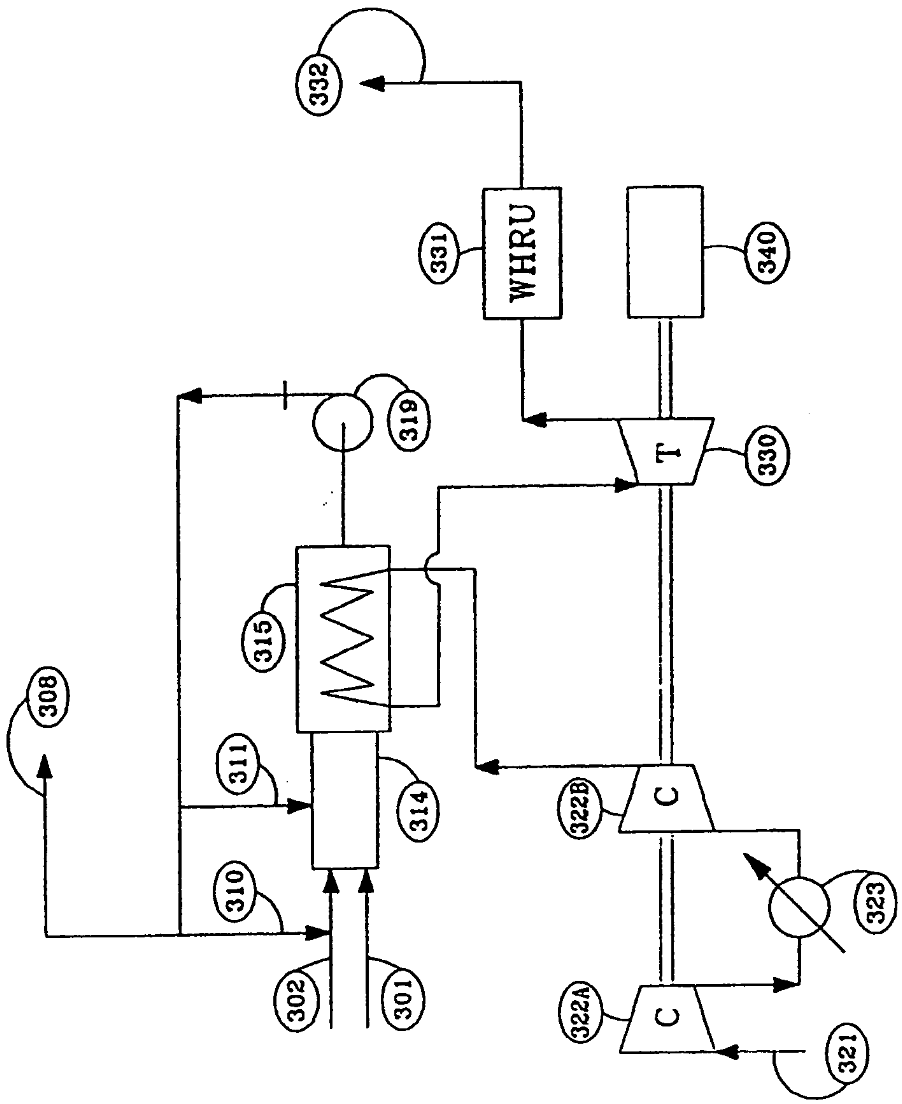


FIG. 2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322B
C
323
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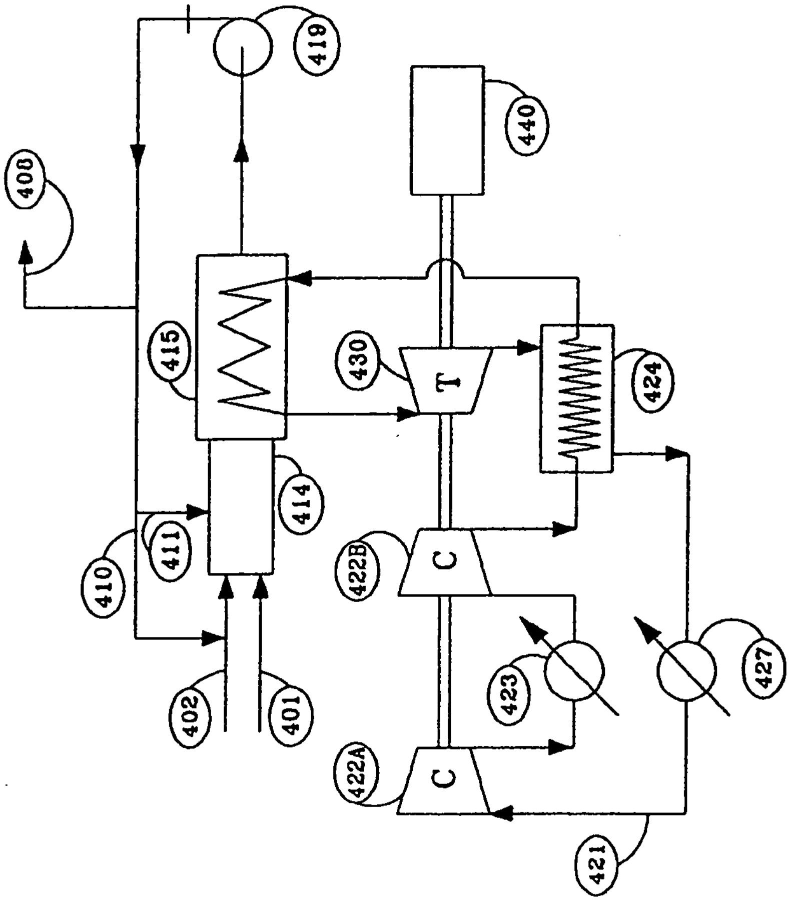
302
301
322A
C
321

FIG. 3


408
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430
T
424
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422B
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423
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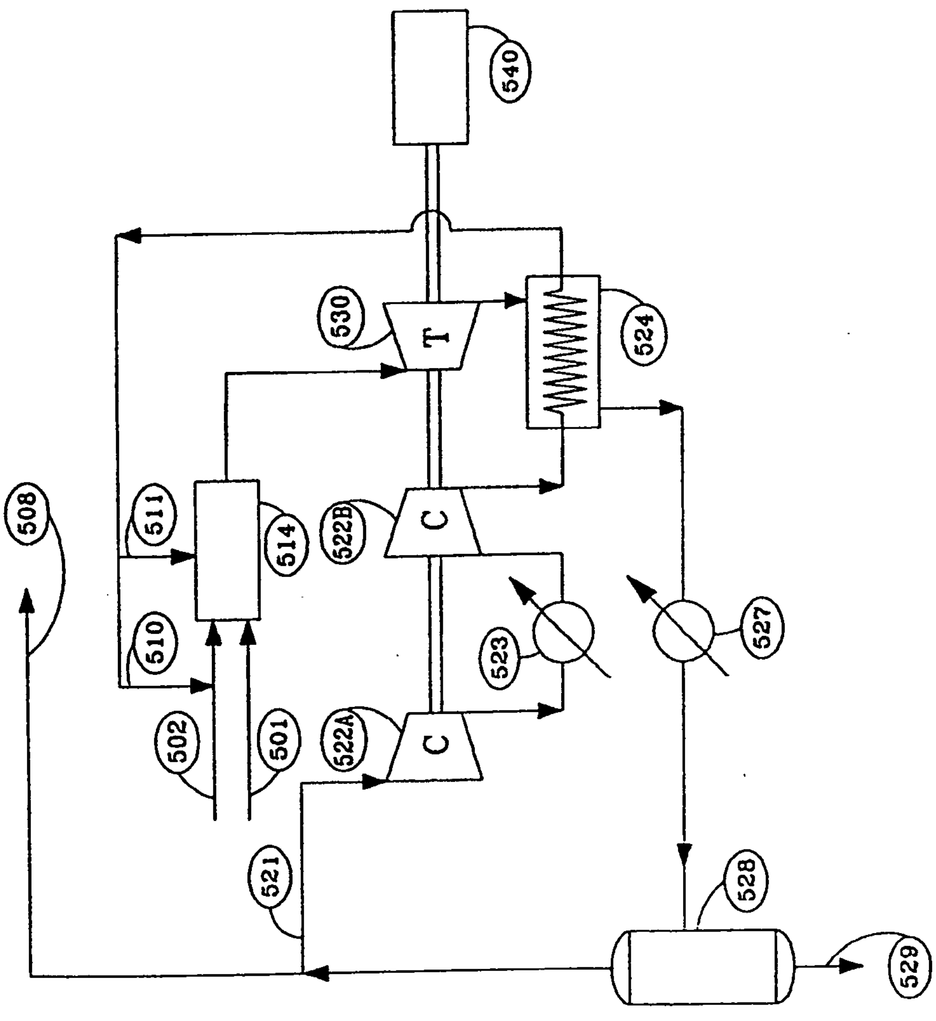
422A
C
421

FIG. 4


540
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522B
C
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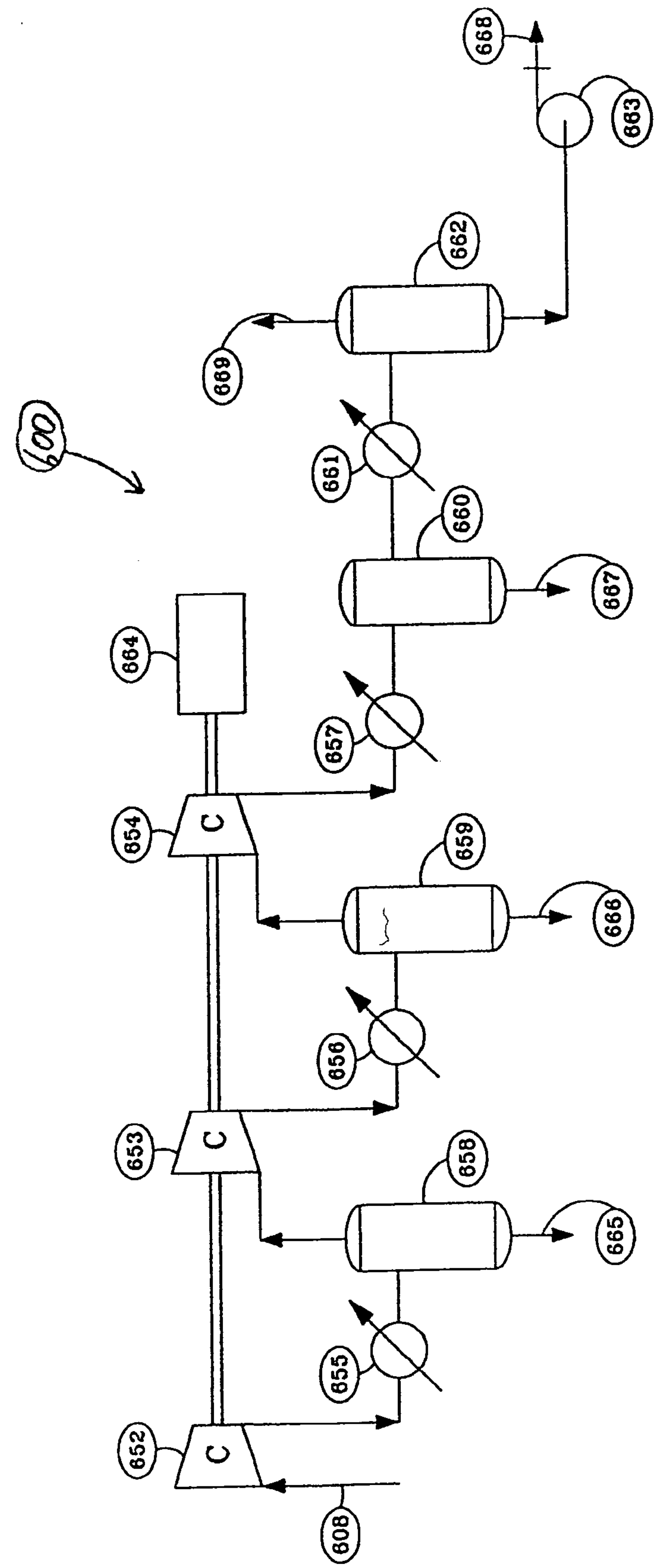
508
510
523
527
502
501
522A
C
521
528
529

FIG. 5


600
608
652
C
653
C
654
C
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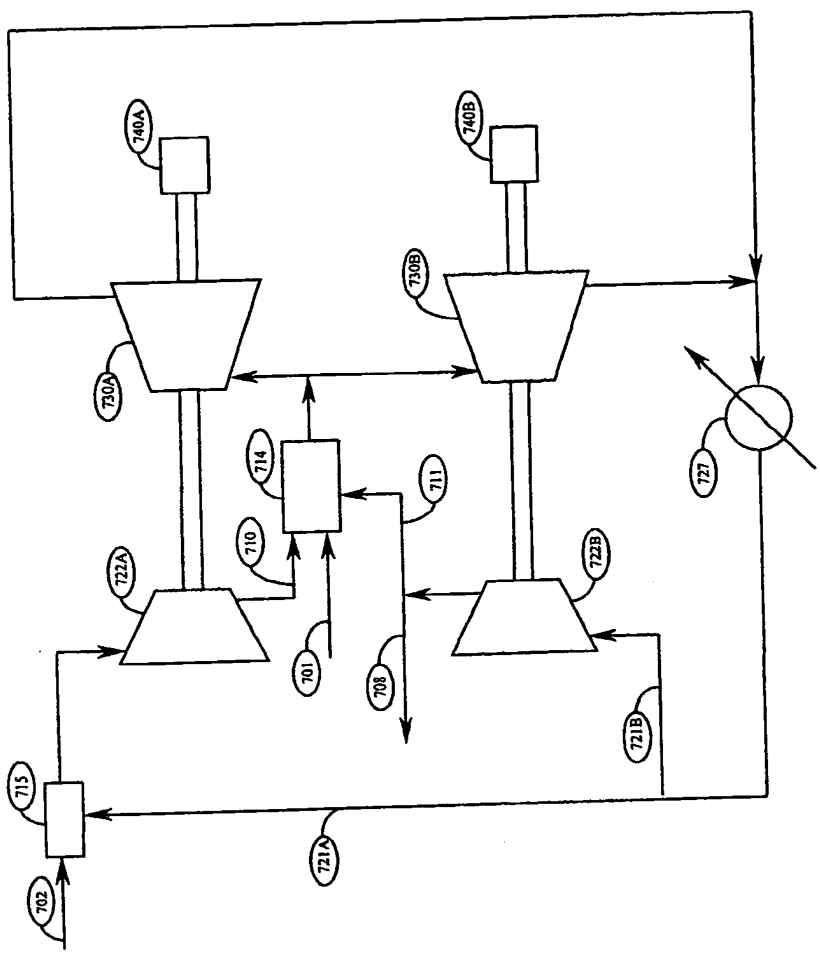
668
669

FIG. 6


740A
740B
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730A
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711
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722A
722B
727
701
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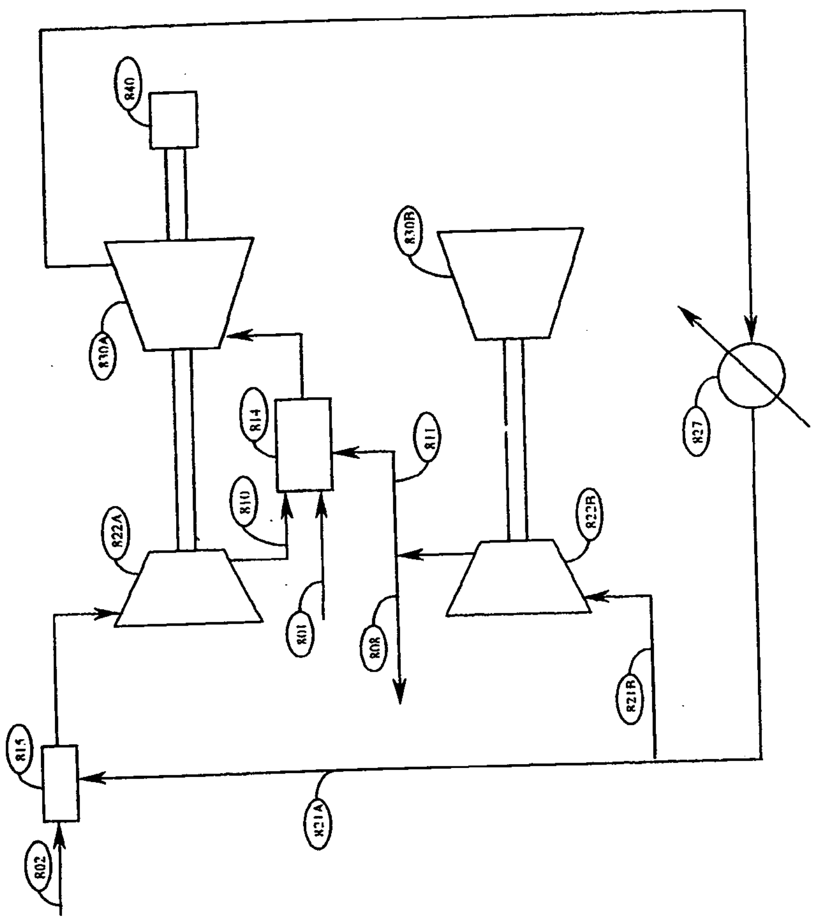
721B
715
721A
702

Figure 7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811
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822A
822B
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808
827
821A
821B
815
802

Figure 8

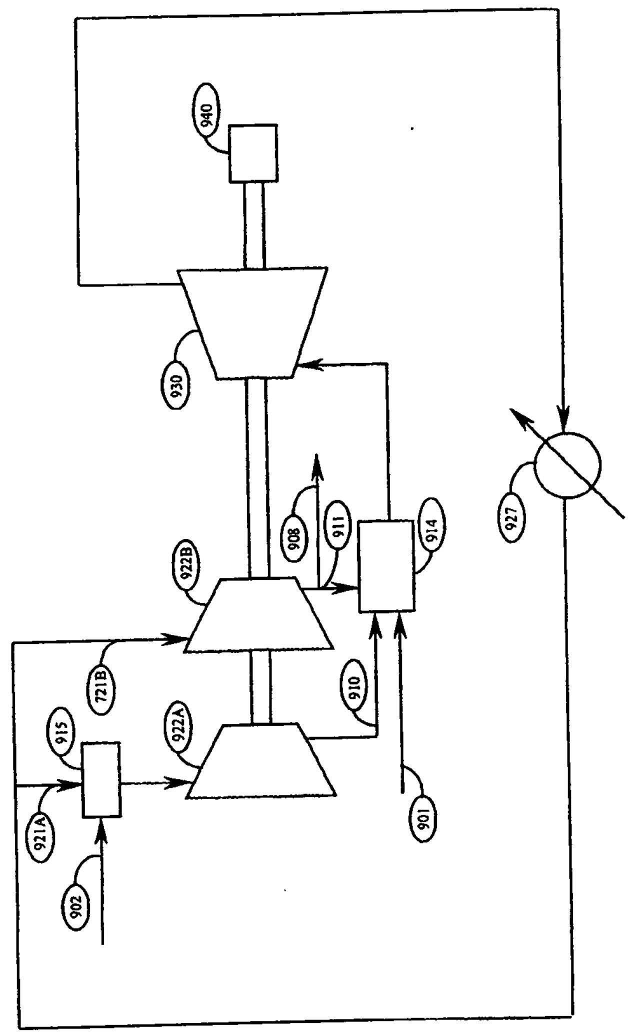

Figure 9

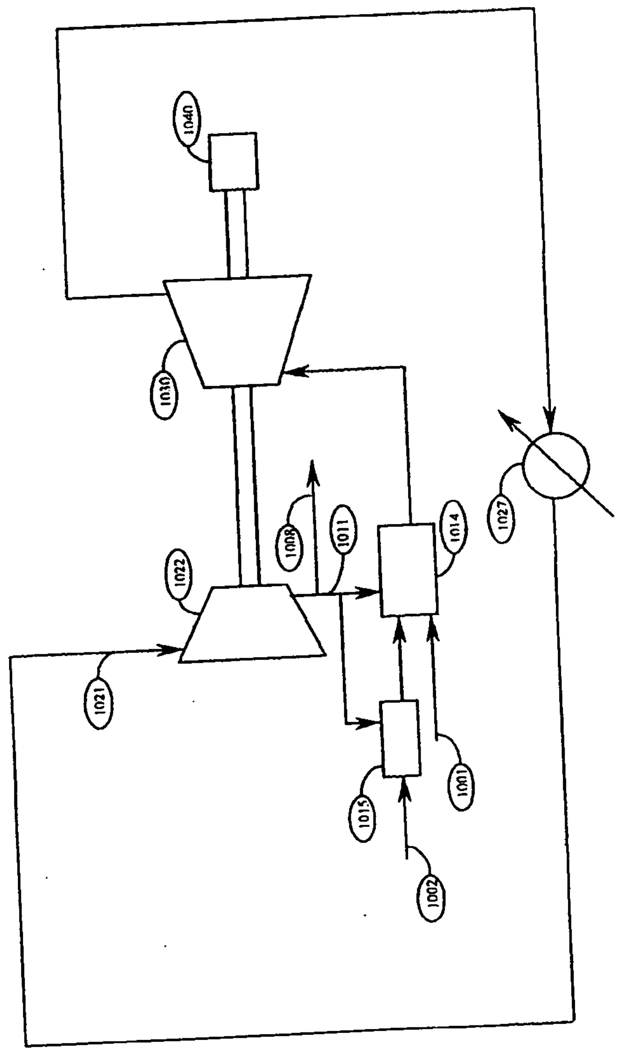

Figure 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 99/00177

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: F02C 3/34
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: F02C, F23C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2140873 A (GENERAL ELECTRIC COMPANY (USA-NEW YORK))), 5 December 1984 (05.12.84), page 1, line 37 - line 50; page 2, line 55 - page 3, line 21, figures 1,6	1-3
	--	
P,A	DE 19810820 A1 (MITSUBISHI HEAVY INDUSTRIES, LTD.), 24 Sept 1998 (24.09.98), column 3, line 1 - line 50, figure 1	1-3
	--	
A	US 5247791 A (P.S. PAK ET AL), 28 Sept 1993 (28.09.93), column 4, line 31 - column 5, line 58, figure 1	1-3
	--	

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search 14 Sept 1999	Date of mailing of the international search report 27-09-1999
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Tomas Lund / MR Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 99/00177

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Patent Abstracts of Japan, abstract of JP 1-8319 A (MITSUI ENG & SHIPBUILD CO LTD), 12 January 1989 (12.01.89), the whole document --	1-3
&	JP 64-8319 A (MITSUI ENG % SHIPBUILD CO LTD), 12 January 1989 (12.01.89), figure 1 -- --------	1-3

INTERNATIONAL SEARCH REPORT

Information on patent family members

30/08/99

International application No.
PCT/NO 99/00177

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB 2140873 A	05/12/84	CH 666253 A,B	15/07/88
		DE 3419216 A	06/12/84
		FR 2546976 A,B	07/12/84
		IT 1175501 B	01/07/87
		IT 8421164 D	00/00/00
		JP 60040733 A	04/03/85
		US 4528811 A	16/07/85
DE 19810820 A1	24/09/98	CA 2231749 A	19/09/98
		JP 10259736 A	29/09/98
US 5247791 A	28/09/93	US 5175995 A	05/01/93
JP 64-8319 A	12/01/89	NONE	